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NOTE

AN AZHDARCHID PTEROSAUR CERVICAL VERTEBRA FROM THE HELL CREEK FORMATION (MAASTRICHTIAN) OF SOUTHEASTERN MONTANA

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In July, 2002 field crews from the Burpee Museum of Natural History collected a partially articulated tyrannosaur skeleton from the Hell Creek Formation of Carter County, Montana. During preparation of the tyrannosaur, an isolated cervical vertebra of a large azhdarchid pterosaur was discovered in one of the field jackets. The Azhdarchidae are a family of large to giant pterodactyloid pterosaurs, known principally from fragmentary remains, found in Cretaceous rocks around the globe. This family contains some of the latest, and largest, pterosaurs. *Quetzalcoatlus northropi* from the Javelina Formation (Maastrichtian) of the Big Bend National Park in Texas, for example, had an estimated wingspan of 11–12 meters (Langston, 1981). *Arambourgenia philadelphiae* (Nesov, 1984) with its estimated wingspan of over 12 meters (Frey and Martill, 1996; Martill, et al., 1998) and *Hatzegopteryx thambema* from the late Cretaceous Hateg Basin of western Romania (Buffetaut, et al. 2002, 2003) may have been even larger.

The only published records of pterosaur remains from the Hell Creek Formation are two indeterminate specimens, which have been recorded from North Dakota, but not described (Johnson et al., 2000; Pearson et al., 2002). Due to the rarity of pterosaur remains in the Hell Creek this specimen merits a brief description here.

Institutional Abbreviations—**BMR**, Burpee Museum of Natural History, Rockford, Illinois; **TMM**, Texas Memorial Museum, Austin, Texas.

SYSTEMATIC PALEONTOLOGY

PTEROSAURIA Kaup, 1834
PTERODACTYLOIDEA Plieninger, 1901
AZHDARCHIDAE Nesov, 1984
cf. *QUETZALCOATLUS* Lawson, 1975

Material—BMR P2002.2 is a single, nearly complete cervical vertebra of a large pterosaur. The specimen is housed in the paleontology collections of the Burpee Museum of Natural History in Rockford, Illinois.

Locality—BMR P2002.2 was collected on public land under jurisdiction of the Federal Bureau of Land Management in northwestern Carter County, Montana, Burpee Museum locality number K-12. It was collected from rocks of the Hell Creek Formation (latest Maastrichtian). In southeastern Montana, the Hell Creek averages 100 m in thickness. The cervical described here was collected approximately 60–70 meters above the base of the Hell Creek. Strata exposed at the collecting locality preserve a fining upward sequence of sediments. The basal unit is a thick, poorly sorted sandstone. This sandstone exhibits weakly developed cross bedding. The pterosaur cervical occurred near the top of this sandstone. Occasional specimens of angiosperm leaves, some preserved curled or otherwise cutting across bedding, were the only other fossils encountered in this sandstone unit, which is thought to represent point bar deposits. The sandstone is in turn overlain by a clay ball conglomerate, which contained the tyrannosaur skeleton and which is overlain by laminated clays containing abundant remains of aquatic plants, principally *Pistia corrugata*. The clay layers grade upwards into blocky shale with root casts. The sequence of sediments preserved at the collecting site is interpreted as a package of sediments which record a stream avulsion and subsequent development of an oxbow lake.

Description—BMR P2002.2 consists of an isolated cervical vertebra of a large pterosaur. The vertebra has been crushed laterally (Figs. 1, 2) but is otherwise essentially complete. It is missing one postzygapophysis, a portion of one postexapophysis, and parts of the neural spine. Despite crushing, the cortex of the bone is well preserved. The vertebra is procoelous and extremely elongate. As preserved, it is 369 mm long and, at the midpoint of the centrum, where the effects of crushing are most severe, it is 23.2 mm in height and averages only 7 mm in width. The interior of the centrum is partially filled with matrix indicating that, in life, it was essentially a thin-walled, hollow tube.

The anterior face of the neural arch bears three foramina. The centrally situated neural canal is the largest of the three openings and is roughly triangular in plan. This is flanked by a pair of smaller, ovate openings that are interpreted as pneumatic foramina. The neural arch bears a pair of well-developed prezygapophyses, which are horn-like and only slightly divergent. A well-developed, oval, articular facet is present on the dorso-medial surface of the prezygapophysis. A small, oval, slit-like opening is present on the anterior face of the centrum just inferior and medial to the base of each prezygapophysis.

These openings extend into the centrum, forming canals that open onto the lateral surface of the vertebra just posterior to the base of each prezygapophysis. By analogy with modern birds, these openings are interpreted as vertebral arterial (transverse) canals. A shallow groove extends caudally, and slightly ventrally, from the posterior opening of the transverse canal for a distance approximately equal to the length of the prezygapophysis. The ventral face of the centrum is marked by a well-developed, rather sharp, ridge-like hypapophyseal process. However, the sharpness of this process may be somewhat exaggerated by the extreme lateral crushing that the vertebra has suffered. The anterior articular surface of the centrum is concave and its margins approximate an equilateral triangle in outline with the apex directed ventrally. In addition, several minute circular foramina, possibly for blood vessels, are present on the lateral surface of the centrum near its anterior margin.

Except toward its ends, the centrum comprises a long, slender, essentially hollow tube. Due to its tubular construction this portion of the centrum displays the greatest degree of diagenetic distortion. The cortex in this region of the bone is extremely thin, averaging only 1.5 mm in thickness, and is broken into a mosaic of small pieces. The severe distortion of the vertebra makes reconstructing the original diameter somewhat difficult. However, it appears to have been uniform in diameter for much of its length, expanding only at its anterior and posterior ends as in azhdarchid mid-cervicals generally.

The neural arch is a low, vaulted structure indistinguishable from the centrum except near the ends of the vertebra. The neural spine is reduced for most of its length, being elevated into a low ridge only at the anterior and posterior ends of the bone.

The posterior end of the vertebra, greatly deformed by the crushing, bears a pair of lateral exapophyses, which are separated ventrally by a broad shallow groove. Only a portion of the right postexapophysis is preserved. The left postexapophysis, which is complete, is horn-like. A shallow fossa appears above the postexapophysis, on the lateral surface of the vertebra near its posterior end. At the anterior end of this fossa is seen a vertical, slit-like opening interpreted as a pneumatic foramen. A wide and shallow sulcus extends posteriorly from the fossa to the end of the vertebra, a distance of approximately 44 mm. The posterior condoyle

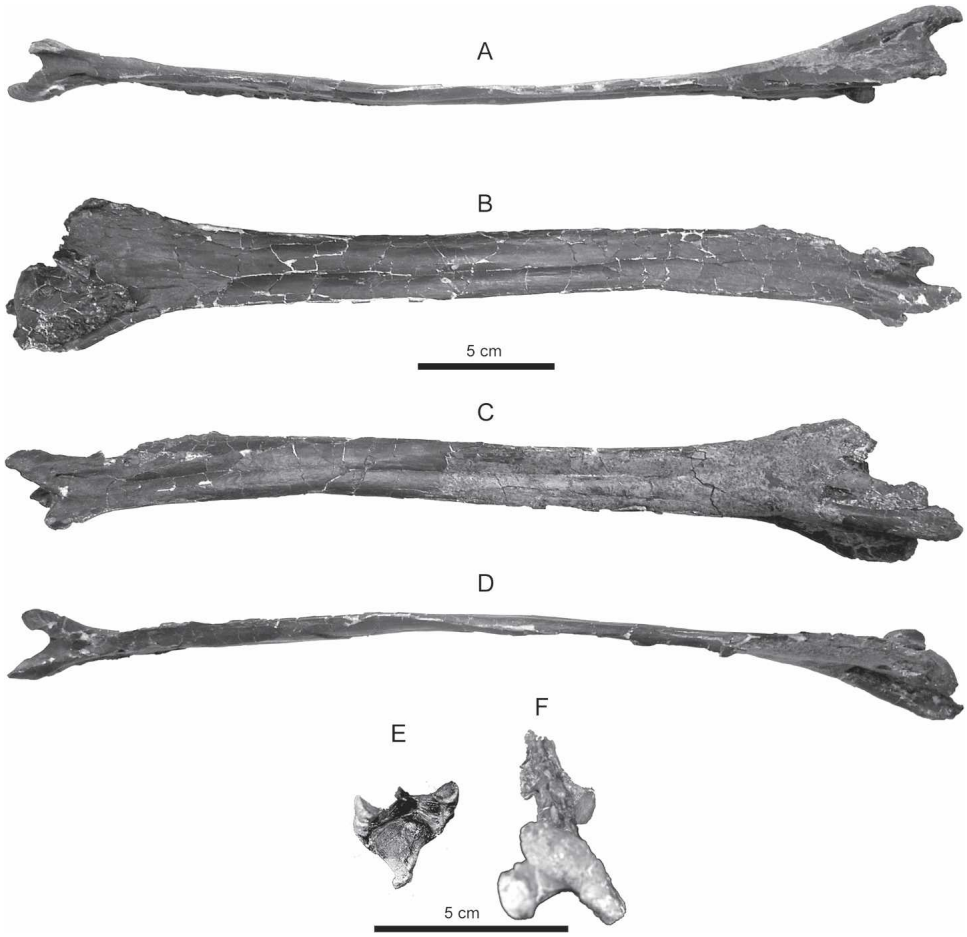

FIGURE 1. Mid series cervical vertebra (BMR P2002.2) of cf. *Quetzalcoatlus* sp. in **A**, ventral aspect; **B**, right lateral aspect; **C**, left lateral aspect; **D**, dorsal aspect; **E**, cranial aspect; **F**, caudal aspect.

is well developed and wider than high. It is flanked ventrally by the postexapophysis.

A large part of the right postzygapophysis has broken away, leaving only the base. The left postzygapophysis is present and exhibits a well-developed articular facet on its ventro-medial surface. The neural canal, seen from its caudal end, is flanked by a small, vertical, slit-like foramen on each side. A shallow, ovate excavation, possibly the recess for the elastic ligament, occurs above the neural canal. A reconstruction of BMR P2002.2 in dorsal and lateral view is presented in Figure 3.

Based on its preserved characters, BMR P2002.2 can be identified as a mid-series cervical vertebra from a pterosaur of the family Ahzdarchidae. This assignment is based on the totality of traits preserved in the vertebra, including its extreme length, greatly reduced neural spine, and a tubular neural canal suspended within the lumen of the centrum (except at the ends of the neural arch). The stratigraphic position of the vertebra is consistent with its identification as that of an azhdarchid pterodactyl.

Comparisons and Discussion—Because azhdarchid cervical vertebrae are hollow, they commonly suffer from varying degrees of diagenetic distortion. Typically, such vertebrae are crushed (flattened) dorsoventrally. The lateral crushing of BMR P2002.2 is unusual and complicates comparison with other specimens. Several examples of azhdarchid cervical vertebrae have been described. One of us (MDH) recently had the opportunity to examine six composite cervical series of *Quetzalcoatlus* sp. in the collections of the Texas Memorial Museum, Austin. These vertebrae were collected in the 1970s and 1980s by Dr. Wann Langston Jr. and his students in Big Bend National Park, Brewster County, Texas (Lawson, 1975; Kellner and Langston, 1996). The neck of pterodactyls is generally conceded as comprising nine vertebrae, some of which are very long and tube-like (Howse, 1986). The mid-series cervicals, C-3 thru C-7, have long vertebral bodies of which those of C-5 and C-6 are distinctly longer and more slender than the others. BMR P2002.2 resembles a putative fifth cervical of *Quetzalcoatlus* sp. from the Maastrichtian Javelina Formation in Texas (TMM 42180-2), although BMR P2002.2 possesses an apparently more robust hypapophyseal process (which restricted ventral deflection of the neck) at its anterior end. We do not attribute much importance to this difference, however, owing to the substantial deformation suffered by both specimens. However, BMR P2002.2 is relatively gracile by comparison with the Texas material. BMR P2002.2 is 348 mm in length (exapophyses to caudal condoyle) whereas the cervical of *Quetzalcoatlus* sp. is 394 mm long. BMR P2002.2 is severely crushed transversely and at midlength is only 5 mm thick. The corresponding measurement of the dorsoventrally crushed TMM 42180-2 is 34 mm. The distortion complicates comparison, but assuming a near circular cross section of both vertebrae, the diameter of the uncrushed Burpee Museum vertebra would have been about 18.25 mm at midlength whereas that of TMM 42180-2 was about 30.5 mm. The slenderness of BMR P2002.1 is also reflected by a transverse diameter across the prezygapophyses of 22.25 mm compared to an estimated width of ~38 mm in the cervical of *Quetzalcoatlus* sp. (only one zygapophysis is preserved in the specimen, and the anterior end of the vertebra has been expanded transversely by crushing, preventing precise measurement of its width). A comparable disparity in width exists at the posterior ends of the specimens, but distortion precludes accurate measurements. It seems unlikely that the difference in width between the two vertebrae would have been eliminated by an increase in length of the BMR P2002.2 specimen to equal that of the fifth cervical of *Quetzalcoatlus* sp.

BMR P2002.1 does seem similar to the fifth cervical *of Quetzalcoatlus sp*. However, the distorted condition of the specimen precludes its referral to any known azhdarchid species. We therefore assign it to the Azhdarchidae incertae sedis. Langston (1981) has estimated the wingspan of *Quetzalcoatlus* sp. from Texas at 5.5 m. In light of the correspon-

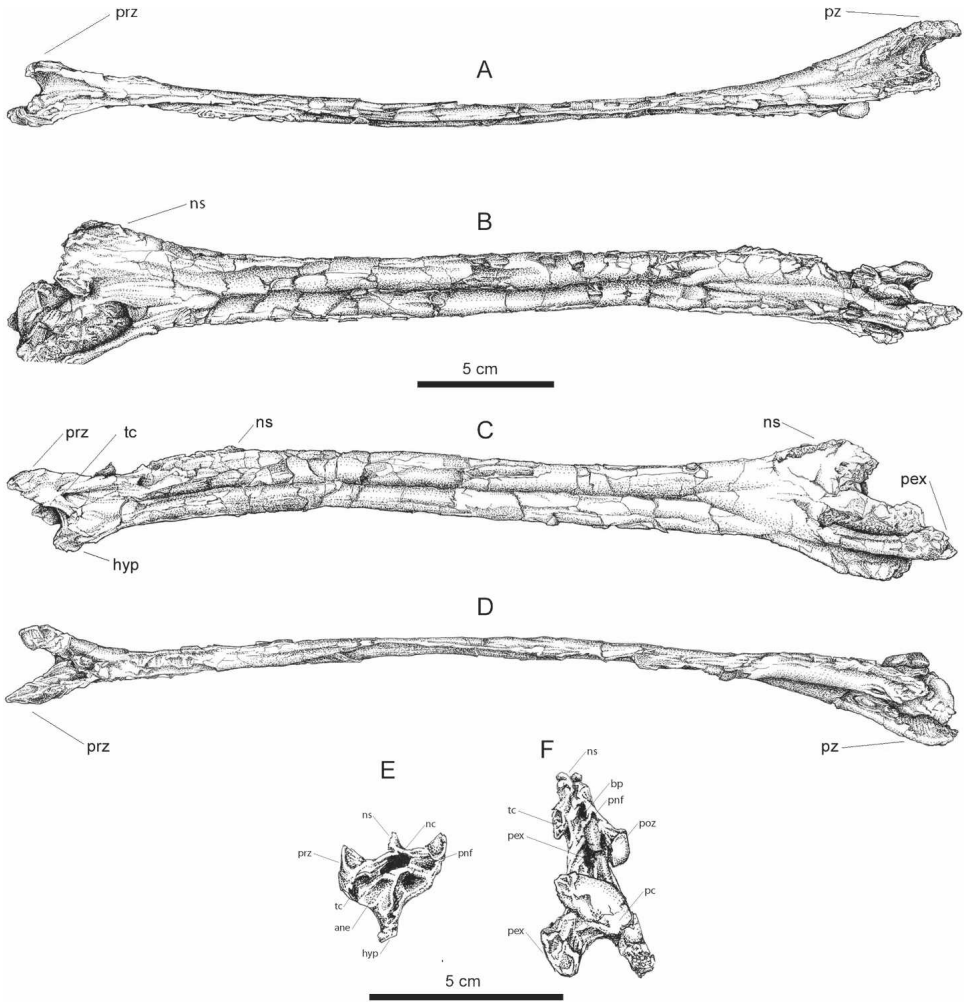

FIGURE 2. Drawings of mid series cervical vertebra (BMR P2002.2) of cf. *Quetzalcoatlus* sp. in **A**, ventral aspect; **B**, right lateral aspect; **C**, left lateral aspect; **D**, dorsal aspect; **E**, cranial aspect; **F**, caudal aspect. **Abbreviations**: **anc**, anterior cotyle; **bp**, blind pocket; **hyp**, hypapophysis; **nc**, neural canal; **ns**, neural spine; **pc**, posterior condoyle; **pex**, postexapophysis; **pnf**, pneumatic foramen; **poz**, postzygapophysis; **prz**, prezygapophysis; **tc**, transverse canal.

dence in size and morphology between the Texas specimens of *Quetzalcoatlus* sp. and BMR P2002.2, an estimate of 5.0 to 5.5 m for the wingspan of the Burpee azhdarchid is probably appropriate.

Theropod dinosaurs may have occasionally preyed upon, or scavenged, the cadavers of pterosaurs. Currie and Jacobson (1995) report a specimen of an azhdarchid pterosaur from Dinosaur Provincial Park, Canada, that shows evidence of having been eaten by a member of the theropod dinosaur genus *Saurornitholestes*. As well, Buffetaut et al.

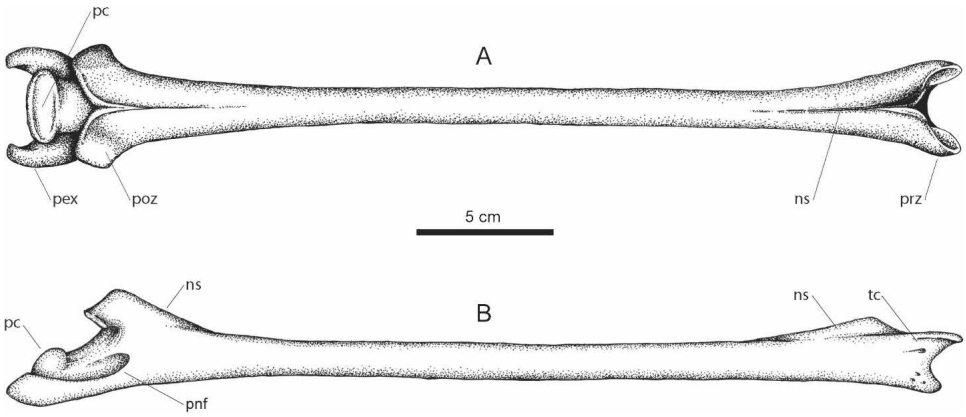

FIGURE 3. Drawing of reconstructed mid series cervical vertebra (BMR P2002.2) of cf. *Quetzalcoatlus* sp. in **A**, dorsal aspect; **B**, right lateral aspect. Abbreviations as in figure 2.

(2004) report an ornithocheirid pterosaur vertebra from the Lower Cretaceous Santana Formation of Brazil with a broken tooth of a spinosaurid theropod embedded in the bone. Although BMR P2002.2 was found immediately beneath the skeleton of a tyrannosaur, all damage to the specimen appears to be attributable to diagenetic causes. The presence of the two fossils in the same field jacket was a result of the accidental juxtaposition of the remains. As it is unlikely that a fragile, elongate azhdarchid cervical could survive much transport in a fluvial environment without sustaining significant injury; its completeness indicates that it was transported only a short distance before coming to rest on the point bar sands.

While azhdarchid remains have not been described previously from the Hell Creek Formation, an azhdarchid cervical has been reported from the Lance Formation of Niobrara County, Wyoming (Estes, 1964). The specimen consists of the anterior half of a fifth or sixth cervical. We estimate that the complete bone would have been approximately 240–260 mm long, and thus somewhat smaller than BMR P2002.2. The Lance Formation consists of laterally equivalent sediments of the same age and made up of the same types of floodplain deposits as the Hell Creek. The Javelina Formation of Texas is also composed chiefly of rocks formed in continental floodplain environments (Lehman, 1987). Azhdarchid remains have also been reported from continental deposits of the Two Medicine Formation (Campanian) in Montana (Padian, 1984; Padian and Smith, 1992; McGowan et al., 2002) and the Oldman Formation (Campanian) of Alberta (Currie and Russell, 1982). The occurrence of this group in continental sediments of the Hell Creek Formation is, therefore, not surprising.

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